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A Study of Earth Radar Returns from Alouette Satellite

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Richard K. Moore [1963] ref

Principal Investigator

## Introduction

The Center for Research, Inc., Engineering Science Division, of the University of Kansas, is studying the ground returns observed by the Alouette top-side ionosphere sounder. Actual reduction of observations will start during late November, 1963. The previous time has been devoted to obtaining records and equipment, to planning the reduction and analysis program, to studying the characteristics of the Alouette as an instrumentation radar, and to development of theories that might be tested using the Alouette data.

Duplicate tapes of the requested Alouette data were received from the Canadian Defense Research Telecommunications Establishment in mid-October. Since then, it has been possible to work on details of the data reduction procedure that were impossible to anticipate.

Theoretical work sponsored in part by this grant and in part by NsG 298 has resulted in two papers that have been submitted to the Journal of Geophysical Research for publication. One paper presents a refined approach to the randomly-located-facet theory of electromagnetic scatter from rough surfaces. The other utilizes the theory and a new autocorrelation function of surface heights to fit the lunar radar data of Evans and Pettingill over a much wider range of angles than any theory has permitted previously. This paper has also been accepted in abstract form for presentation at the fall IEEE-URSI meeting in Seattle during December.

## Preliminary examination of data

Mr. B. E. Parkins and Dr. R. K. Moore visited the Defense Research Telecommunications Establishment at Ottawa on 28 May, to examine the ionograms and tapes and plan future action. Mr. A. K. Fung spent a week at Ottawa about the first of August making specific selections based on criteria established during the interim period.

The relatively small number of ionograms containing good ground echoes is somewhat surprising. Nevertheless, in the tremendous collection of ionograms obtained by the Alouette in the past year, there are many more ground echo records than could be analyzed in a program of this magnitude. Consequently, Mr. Fung was able to select ionograms obtained on 13 different days and in a variety of places throughout the world for further analysis.

The selection process is complicated by ionospheric disturbance of the received echoes as well as by lack of ground echoes on many sweeps. The maximum frequency of the Alouette is sufficiently close to the critical frequency for the F-layer of the ionosphere that turbulence in that layer, as evidenced by "spread F" echoes from the ionosphere, causes some stretching of the pulse received from the ground. In cases where such stretching is present, it is, of course, impossible to determine whether the pulse shape was determined by the ground echo itself or by the ionosphere. Accordingly, it was necessary to omit many records that showed signs of F-layer spreading.

Records of this sort are especially common in the polar regions, so that it is unlikely that any suitable arctic or antarctic ground echoes can be analyzed.

Northern hemisphere stations are subject to an excessive amount of interference from radio stations. As a result, observations from southern hemisphere telemetry stations are predominant in the records selected. This has made it a little more difficult to find suitable records where the satellite was over land. It is believed that as representative a selection as possible has been made.

Completion of the analysis of the records will be impossible until trajectory information is obtained from Goddard Space Flight Center. Apparently contact was made with the wrong office at GSFC initially. Recently a visit to GSFC appears to have straightened out this situation, and the records are expected in Lawrence shortly.

Data processing to date and equipment procurement

Arrangements were made with DRTE to have tapes prepared at their recording station as copies of the original tapes. These copies were to be recorded on four channels of a seven-channel tape. One channel contains the radar video signal. Another contains a signal, determined by the AGC of the receiver in the satellite, that is necessary to determine the receiver gain for any particular return. A third channel was to have contained voice information recorded at the telemetry station and a fourth was to have contained time codes. For some reason, neither of these last two channels appears to have been recorded.

Rather than wait for further recording, it was decided to determine the time from log information and from time codes on ionograms furnished by DRTE. Since it is not difficult for us to make ionograms where there is question, identification of the time, and hence location of the satellite during a particular run, should be relatively simple.

Some of the AGC curves that we need at the high frequency end of the sounder's sweep are not available. Where possible, these are being prepared by DRTE. Some apparently cannot be prepared because they would have to be obtained from the sounder equipment itself, which is in orbit.

The dipole antenna used with the sounder has a gain that varies with both frequency and orientation. The satellite contains no orientation sensor, so these effects will have to be estimated.

Initial tests indicate that suitable photographs of the oscilloscope traces can be made with the system we have assembled. Bulk photographs were not possible prior to November 1, because some of the components were not available. The camera which was originally delivered in June was found to be faulty in that the film magazines would not fit properly. Negotiations to get this straightened out and ultimate shipment of the camera back to the factory involved several months. At the time of writing this report, the camera has just returned to Lawrence.

Preliminary checks have been made using a recorder and oscilloscope at the University of Kansas Medical Center in Kansas City. The facility was not available for bulk recording. Since the tapes themselves did not arrive in Lawrence until mid-October, this has not resulted in a significant delay in the program.

At the start of the project some effort was expended in determining what recording equipment would be suitable. After the consultation with DRTE personnel, it was concluded that the Sanborn-Ampex model 2000 with suitable plug-in units could meet the required specifications. Accordingly, such a unit was purchased. It was delivered on July, 16, 1963.

Electrical performance of the Sanborn-Ampex 2000 is specified essentially the same as that of the Ampex FR-100 which is used by DRTE. The specified frequency response in each mode for a given tape speed is about half that of the FR-600 used in NASA telemetry stations. Nominally, the FM recording system for the FR-100 must be operated at 30 inches per second to obtain a frequency response to 10 kc. DRTE personnel have found, however, that it is possible to get adequate frequency response for the Alouette data by using the 10 kc system at 15 inches per second and restricting the frequency modulation level to 40 per cent. After some discussion with the Sanborn factory engineer and after obtaining some special curves run under these conditions on the Sanborn-Ampex 2000 by him, it was concluded that the same method could be used with the Sanborn-Ampex 2000.

Individual pulses must be recorded from the satellite sounder for this program. Consequently, it was decided to purchase a strip-film camera that could be used with an oscilloscope. A Fairchild-DuMont type 321A camera was purchased. Although it was initially delivered in June, problems connected with mating of the film magazines to the camera required several exchanges of film magazines with the factory, and finally an exchange of cameras so that final delivery of an acceptable item was not made until November.

A model MPE Recordak microfilm recorder was obtained for data reduction purposes. In this initial study, the more elaborate digital readers did not seem justified.

## Data processing plans

An internal memorandum has been prepared[1] outlining the data reduction problem and planned procedures for handling it.

Briefly, data reduction consists of many steps, including among them the following:

1. Identification of suitable sweeps containing usable ground returns.
2. Time identification of these sweeps.

[1] Chia, Richard Chung, "Data Handling Procedures for Alouette Satellite Ground Returns," Electromagnetic Sensing Laboratory, Internal Technical Memorandum, November, 1963.

3. Filming of record from a particular sweep with long-time base permitting range identification.
4. Filming of record with short-time base permitting pulse spreading measurement.
5. Visual observation on the microfilm reader of pulse amplitude at several points in each pulse.
6. Determining from the film of AGC levels.
7. From examination of several adjacent sweeps, determination of likely antenna gain.
8. Determination of the proper detector characteristic
9. Conversion of pulse displacements on film into pulse amplitudes in sounder.
10. Preparation of median or mean signal amplitude versus time curves for the particular run.
11. Least square solution of integral equation that combines pulse length and ground response to determine ground response.
12. Determination of location of satellite.
13. Comparison with similar results from similar locations.

The thirteen steps enumerated above are somewhat abbreviated. A number of other problems exist with respect to converting the measured characteristics of the Alouette radar into known received amplitudes as determined by the height of a pulse on the film. The effect of the ionosphere must be considered. The effect of the varying frequency of the sounder must be considered. Since only a few pulses on each sweep contain usable ground returns, an analysis of the validity of the mean pulse must be made statistically. Pulses from like grounds are to be compared to try to improve on the sample size, so that the mean pulse curves may be more reliable.

This data reduction and analysis process is just beginning. It is hoped that it can be set into successful operation soon, but it is obvious from the complexity that it will not be possible to do so overnight!

Theoretical Work

During the period that data processing has been delayed by delays in receiving the processing equipment and tapes, theoretical work on radar returns from the ground and the moon has been continued, partly with the support of this grant and partly with the support of a sub-project under University of Kansas NASA grant NsG 298. Two papers have been prepared and submitted to the Journal of Geophysical Research, and one has been accepted for presentation at the fall URSI meeting in Seattle.

The first paper, by A. K. Fung, "Theory of Radar Scatter from Rough Surfaces -- Bistatic and Monostatic, with Application to Lunar Radar Return," shows a more rigorous way to set up the Kirchoff-Huyghens-Fresnel integral for scatter from a rough surface. The autocorrelation function of the ground height above the mean has been shown previously to approximate an exponential. Previous analyses with the exponential correlation, however, required some approximations that this paper shows are unnecessary. The result is a more complete theory for such a description of the ground.

The second paper by A. K. Fung and R. K. Moore, "Effects of Structure Size on Moon and Earth Radar Returns at Various Angles," uses a unique autocorrelation function to determine rough-surface scatter. This function approximates the exponential normally observed within the precision of the normal observation (calculation from contour maps). For very small distances, compared with the characteristic distance for the main exponential, this function approaches first one and then another exponential with steeper declines. The consequence of this autocorrelation function is that the calculated curve of radar return signal versus angle fits the Evans and Pettingill[2] lunar data from vertical out to 85 degrees with the vertical. Since no other fit has been achieved with anywhere near the same precision beyond about $30^{\circ}$, we believe this represents a major contribution to the theory of scatter from rough surfaces, like the moon or the earth. If possible, the results will be applied to the earth scatter observed by the Alouette sounder.

## Conclusion

The first six months have been spent in preparing for handling Alouette data. It is hoped that most of the next six months can be spent in handling them. It appears likely because of the delay in getting started on data reduction that it will be necessary for a time extension on the grant.

Theoretical work believed to be of considerable importance in interpretation of ground scatter and in moon scatter has been accomplished during the period of the grant.

## Acknowledgement

The cooperation of many individuals at the Defense Research Telecommunications Establishment, Shirley Bay, Ottawa, Canada, is gratefully acknowledged. Especial thanks are due to Dr. E. S. Warren.